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The mechanics of seed-dispersion in Ricinus communis

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Seed-dispersion is a matter of such common knowledge that almost everybody has had some experience with some special adaptation exhibited by certain plants, one way or another. The more common agents which serve the plant's purpose are wind, water and animals. But there are various other means, not so apparent, and consequently not so well known, which contribute towards the well-being of the plant in its struggle for space (or room) in which to flourish.

One method, not so uncommon as is generally supposed, is here examined in some detail with a view towards gaining some definite knowledge in regard to the actual dynamics involved in the projection of the fruit. To illustrate this problem the castor bean was selected.

The advantage to a plant of some special means of transporting its seed is so apparent that it needs no comment. How the plant came to possess this special means, is a question which largely belongs to the problem of evolution, and is not here discussed.

To understand the whole question fully it is necessary to examine all the conditions. Each plant of the castor bean produces on an average about five flower-clusters, the axis of each cluster being nearly perpendicular to the ground. On each cluster there are about fifty-eight fruits, each borne on a peduncle which inclines about forty-five degrees to the vertical. The axis of each fruit is at right angles (approximately) with the peduncle and inclining towards the ground at an angle, therefore, of forty-five degrees with the vertical. At this angle, one of the fruit-parts (carpels) would be projected at an angle of forty-five degrees above the horizontal (theoretically the angle of projection which produces the greatest range). But, as the carpels commence to separate, they do so from the *base* of the fruit, thereby lessening the angle of that one carpel some five or ten degrees; and, since atmospheric conditions have to be taken into account, forty degrees is the angle which gives actually the greatest range, so it is easy to see that the plant has the best actual position to project its seed to the greatest distance. The other two carpels cannot be in so good a position, but the plant appears to be able to sacrifice several in order that a *few* seedlings may obtain a place of advantage the following season. It sacrifices *two* carpels that *one* may have the maximum of benefit in this respect.

As the fruit ripens it loses water gradually and begins to split open septicidally from the base and keeps on splitting thus, until a point is reached about three millimeters from the apex. While this is going on, the carpels are not only separating from one another, but also from the central column which is a continuation of the fruit-stalk. On three sides of the apical end of this central column are the three placental processes. Each projects into the locule to some extent, but the seed breaks off early from the placenta, leaving this central column wholly separate from the three carpels, yet suspending them because the processes referred to extend into each carpel through a comparatively large opening near the apical end. The carpels are therefore suspended much in the same manner as if hanging upon a peg; but as the three are still joined together they cannot be separated entirely from the central column until *one* of the three is removed. This central column, upon separation from the carpels, is left with three projecting flanges which, together with the processes referred to, prevent any alteration in position of the fruit which might possibly result when the carpels become detached from the column. At first glance this would seem to make no difference; but, when we consider that the carpel *first* projected will have the greatest momentum it is of some importance. The carpel with its dorsal side uppermost will have the most sun exposure and will consequently dry out most quickly. This is the carpel which has the best position, and which will most likely reach the maximum range.

A second stage in the process of preparation for actual projection may be said to commence after the carpels are entirely free from the central column. As the carpel dries out, the dorsal wall contracts and this contraction produces a pressure which becomes greater and greater as contraction goes on until the carpel gives way at its weakest point. This is at the apical end, where there are three pairs of tooth-shaped arrangements meeting at a line about three or four millimeters long. Each carpel splits apart at this line with some violence. This acts just as a spring suddenly relaxed; thus the carpel is projected. This splitting is a loculicidal dehiscence and the seed, though projected with the carpel, is at this time, or soon after, released, but not before.

Another structural peculiarity is the prickly surface of the carpel, and this might easily act in conjunction with the explosion, from the fact that any slight disturbance immediately before the carpels were ready to explode, would *cause* the explosion, and these carpels might then attach themselves to such animal as might produce the disturbance. This, however, is not taken into consideration.

To ascertain the magnitude of the energy of expulsion it was necessary first to determine the actual distance some of the carpellary parts were projected. This was done in-doors by hanging the mature fruiting branches in a natural position at a given distance, approximately that of the plant, above the horizontal, and then measuring the actual range which the carpels were projected. The plants in the garden were similarly examined and the results did not differ very materially from those obtained in-doors. The average distance from the vertical, of those carpels which seemed to be projected from the position most favorable of the three carpels, was found to be 3.65 meters, and the average height of the cluster was 1.6 meters. Then, since the angle of rising equals the angle of falling, the real horizontal range would be $3.65 - 1.6 = 2.05$ meters. Since the angle of projection is 40°, then $2v^2.\sin 40^\circ \div 9.8 = 2.05$ meters. $\therefore v = 3.6$ (approx.) meters per second, where v is the velocity of projection. Hence the work done in projecting a body weighing .4 grams (the weight of one carpel with contents) would be

$$\left(\frac{3.6}{9.8}\right)^2 \times 4.9 \times .4 = .264 \text{ gram-meters per sec.}$$
$$= .000264 \text{ kgm. per sec.}$$

Since there are 3 carpels to one fruit, and 58 (average) fruits on one cluster, and 4 (average) clusters on one plant, each plant would do, by the sudden "filliping" of the carpels,

$$3 \times 58 \times 4 \times .000264 \div 76 = .0024 \text{ horse powers per second.}$$

And if each plant requires 4 square feet of ground space upon which to grow, on one acre there would be 10,890 plants; therefore, a measure of the work done in exploding the carpels of the plants on one acre would be

$$10890 \times .0024 = 26.14 \text{ horse-powers per second.}$$[1]

This simply means that the work done is equal to that which one good strong horse could do in 26 seconds. It does not mean the energy that might be required in threshing out the seeds, but it means that energy alone which *causes* the *projection* of the carpels.

It should also be observed that the calculated range was an approach toward a maximum rather than an average, because no account was taken of the fruit which seemed to have simply fallen, or of those projected from a disadvantageous position, although the energy in the latter case would undoubtedly be the same as that exerted in the projection of those which had been discharged from a position of advantage.

The energy expanded by the plant is developed directly from the atmosphere, coupled with the heat of the sun; and indirectly from the cells and contents built up by the plant. Indeed, it is the same quality of energy as that which raises water from the earth into the atmosphere. The part taken by the plant is the preparation of carpels of such a form as will store up this energy for a time and thus make the best use of it by liberating it *all at once*. What this means to the species in successfully contending for space in which to grow, may be best illustrated by a mathematical calculation.

Starting with a given plant, it may be seen from our measurements that the ground covered by the seedlings from this plant would be

In 1 year $3.65^2 \times \pi$ square meters,
In 2 years $7.30^2 \times \pi$ square meters,
In 3 years $10.95^2 \times \pi$ square meters,
In 100 years $365^2 \times \pi = 41.8707$ hectares $=$ 105 acres (approx.).

This does not seem to be a very large area when the length of time is taken into consideration; but it must be borne in mind that this is only *one* means the plant has for scattering its seed. It takes no account of the washing away by water, or the transportation by wind or animals. The calculations are made upon the consideration of the fruit as a *projectile* alone, and from this the attempt is made to see just how much it has to do with the well-being of the plant.